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SOME LABORATORY TESTS OF THE ACCURACY OF THE BELFORT UNIVERSAL RECORDING RAINGAGE

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16. ABSTRACT Laboratory tests were conducted with the Belfort Universal Recording Raingage to provide information on the instruments' response and accuracy with simulated light precipitation rates. Such rates are characteristic of many snowfalls in the Rocky Mountains, and are of particular interest in evaluation of winter weather modification programs in that region.

Simulated precipitation rates in the approximate range 0.01 to 0.10 inch per hour were provided by gravity feed through medical intravenous (IV) units. The flow rates were monitored before and after each test of one to three hours duration by interception and weighing. The total daily simulated precipitation amount was intercepted by a beaker in the gage bucket for later weighing. Gage chart records were carefully reduced for comparison with the simulated precipitation.

Results indicate that over periods of several hours the gage chart traces generally lagged the simulated precipitation. However, this lag in indicated amount averaged only approximately 0.02 inch and was seldom greater than 0.03 inch. For periods of one to three hours, over half the cases had a chart response within $\pm$ 10 percent of the simulated precipitation amount. This is considered remarkable performance, especially in view of the various possible errors which are discussed

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March, 1985

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I. Introduction

Evaluation of winter orographic weather modification programs often requires accurate measurements of small amounts of precipitation. Most winter storms in the Rocky Mountain region, for example, have precipitation totals in the range of a few hundredths to a few tenths of an inch water equivalent. Increases due to seeding may only fractionally affect those small amounts, leading to difficulties in detection of seeding effects. The most commonly used instrument for these measurements is the Belfort Universal Recording Raingage for which the manufacturer's specifications quote an accuracy of 0.5 percent of the full scale travel (0.06 inch for a 12-inch-capacity dual tranverse model) and a sensitivity of 0.01 inch precipitation. A limited review of the literature and consultation with the manufacturer disclosed no test data to substantiate the validity of these specifications. Therefore, a laboratory test program was undertaken to provide this information.

II. Nature and Purpose of Study

The purpose of the experiment was to determine the accuracy of the Belfort Universal Recording Raingage (model 5-780 series). As used here, accuracy is defined as the agreement of the measurement with the "true" value of the quantity measured. Precipitation rates representative of winter snowfall characteristics were investigated. Flow rates in the approximate range 0.25 to 2.5 mm/h (0.01 to 0.1 in/h) were established for periods of one to several hours to simulate snowfall occurrences.

The flow rate during each test period was estimated by intercepting the flow for known time periods just before, and just after, each test period. These two samples were weighed, and the flow rates were calculated and averaged to estimate the flow rate during the test period. During the test period the flow entered a beaker set in the middle of the gage catch bucket. The beaker was weighed after each test to establish the actual total flow into the gage.

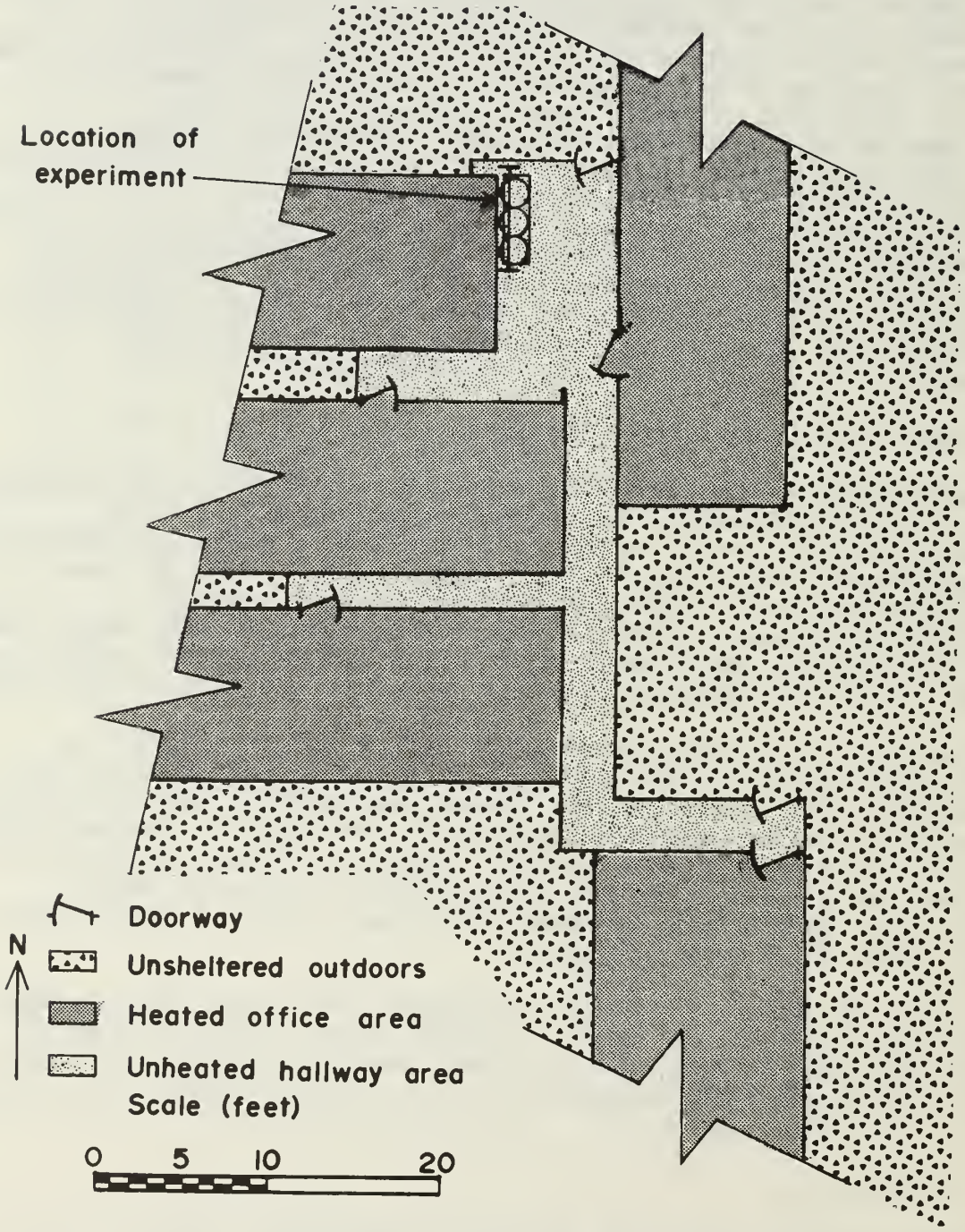
Flow data were plotted and compared with gage chart readings, because the accuracy of the instrument's chart record was of primary interest. In addition, the temporal response of the gage could be evaluated by comparison of the chart trace to the known rate of test flow input.

III. Materials

Three Belfort Universal Recording Raingages (model 5-780 series) with dual traverse measuring capability were used. The housing shroud and collector funnel were removed from each gage assembly to allow convenient operating access. The gages were not equipped with potentiometers or other peripheral equipment that might create operational drag on the system. All

TEST LOCATION

Figure 1



dashpot mechanisms were filled with 10W-40 motor oil. The chart drives were operated for one week for timing accuracy checks before test initiation, and maintained an accuracy of ± 5 minutes per week throughout the test program.

The gages and related experimental equipment were operated in an enclosed, unheated hallway area between Bureau of Reclamation mobile offices at the Miles City, Montana airport (see Figure 1).

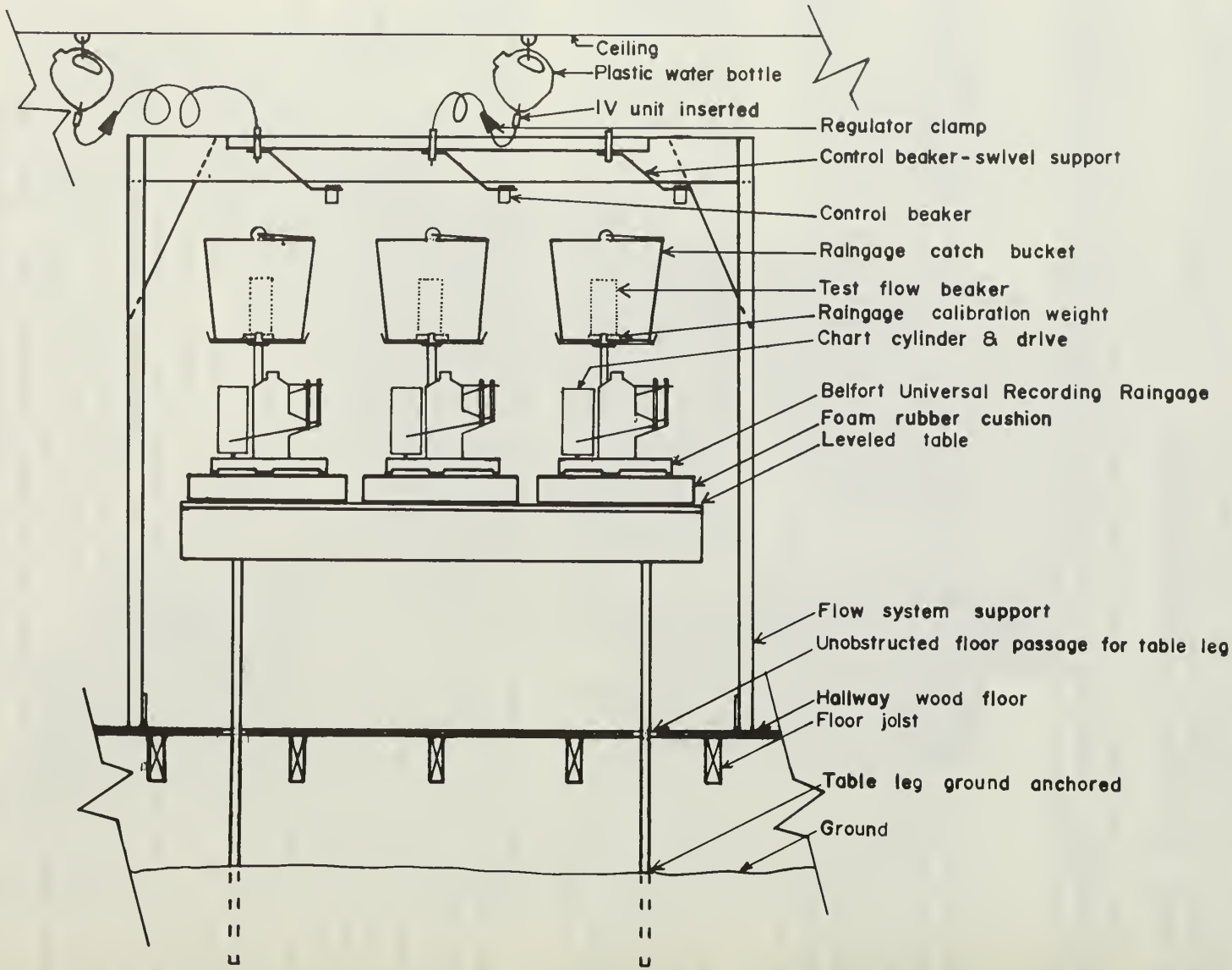
While the hallway area was not heated, the entrainment of air from adjacent offices with passages of personnel and associated opening and closing of doors raised temperatures somewhat above outside ambient levels. Although outside wind effects were totally removed from the experimental setting, passage of personnel or rapid closing and opening of office doors may have resulted in internal drafts. However, such drafts are believed to have had minor impact on the gages.

The gages were set on a table with legs anchored directly to the ground (see Figure 2), which prevented floor vibrations from being transmitted to the gage mechanisms through the table legs. Further vibration control was obtained by placing the gages on a corrugated cardboard sheet glued to a 3-inch thickness of foam rubber. This limited disruptions of the mechanisms to the influence of internal building drafts.

An elevated reservoir system was constructed and mounted to feed into the gages. First a pressurized system was tried, but because of the inconsistent flow rates obtained, a gravity system was finally designed to serve as the precipitation feed. Two plastic water bottles (1 gallon) with a water-ethylene glycol mixture (approximately 80%/20%) were supported from the 6-foot, 10-inch ceiling of the hallway. These reservoirs had vented medical intravenous (IV) units insertd into the base of the plastic reservoirs. From the IV inserts 1/8-inch tubing carried the fluid through a regulator clamp to a position above the raingage catch buckets, where it was allowed to drip into a beaker within the raingage catch buckets. The IV tube was elevated to allow a separate control beaker to be swung into position below the IV feed and above the raingage to intercept the flow into the gage. This enabled measurement of the flow rate by weighing of the intercepted catch and division by the period of time that the flow was intercepted. Due to the slow rates used for the tests, individual drops could be counted. The interval of time between drops was observed and recorded for all tests and used as an approximate indicator for flow-rate adjustment.

The Belfort gages were calibrated prior to test activities in accordance with standard calibration practices. Calibration results, summarized in Table 1, show that accuracy within ± 0.03 inch was obtained over the full 12-inch gage span. The gages were calibrated for a temperature environment of approximately

Figure 2 BELFORT RAINGAGE TEST CONFIGURATION



1° C. This was accomplished by adjustment of each of the 1-inch calibration weights to exactly 823.6 g, equivalent to a water density of 0.9999 g/cm^3 which occurs at 0.5 and 7.5°C. The Belfort instruction manual (1976) states that each calibration weight weighs 822.7 g and is equivalent to a volume of water one inch deep by 8 inches in diameter (Belfort collector orifice diameter). This would be correct at a temperature of either -6.5° C. or +17° C, where the density of water is 0.9988 g/cm^3.

The dual-traverse gages were calibrated on 6 October 1982 over the full 12-inch range with chart paper graduated in inches (Chart No. 5-4047-B).

Individual calibration weights were incrementally placed in the catch bucket during the calibration routine. After each weight was centered in the bucket, the gage's bucket was tapped and the chart drive cylinder was manually rotated slightly to record the pen's trace on the chart. This was done for each increment from 0 through 12 inches. The procedure was then reversed; each of the weights from 12 through 0 inches was removed. Table 1 lists the deviations of each gage from the respective chart inch levels. The calibration checks recorded near the midpoint of the tests are also noted for a single traverse range for each respective gage.

After the calibration was completed, the gages and chart drives were considered ready for test exercises. A calibration weight (823.6 g) was placed in the center of the catch bucket to position the gage's pen arm at an operating range that might be expected under field conditions. This simulated the weight of an evaporation suppressant/antifreeze charge that would be used during winter field operations and would bring the initial level of the gage above 0 inches. This procedure also kept the gage from bottoming out on the platform movement stop screws. If the system were to deviate significantly from the zero calibration level, it is possible that considerable flow could enter the catch bucket while resting on the stop screw, and not be detected by the weighing mechanism.

After the calibration weight was placed in the catch bucket, a second smaller catch beaker was placed on top of the weight within the bucket to receive the flow from the IV tube. This beaker, with an evaporation suppressant added, was weighed before placement. The volume of evaporation suppressant was approximately 10 cm^3 and generally weighed nearly 8.2 g (equivalent to 0.01 inch of precipitation). Texaco aircraft hydraulic oil BB (petroleum base) was used for an evaporation suppressant. The small catch beaker was used to allow for convenient weighing of the total flow catch after each test. In addition, with a smaller beaker, the surface area of the liquid was reduced. This required less evaporation suppressant and decreased the opportunity for evaporation.

A horizontal swivel arm was located above the catch bucket to hold a 50-mL beaker. When needed, the 50-mL beaker was swung into position below the IV feed to intercept the flow for control measurement purposes.

IV. Procedures

Several test and system design variations were tried before the system was considered acceptable. Shakedown of the system was basically complete on 10 November 1982. Of the fifteen tests conducted on or after 15 November, only those that provided sufficiently stable flow rates and had no other operational or procedural faults were used to assess resolution capabilities (see Table 2). The daily routine of each test was varied slightly, but always utilized the same general procedural and measurement techniques as outlined below:

To start each test, a chart was first mounted on a chart drive cylinder, and fastened with tape to prevent the "bump" that would have been caused by the metal chart clip which was not used. The clock was manually wound before the cylinder was positioned on the drive. The fluid feed was first allowed to fall into a "waste beaker" while the desired flow rate was established. When the drip rate appeared constant, the waste beaker was removed and the feed was allowed to flow into a 50-mL control beaker, usually for 30 minutes. This flow was referred to as the "control flow." The pen trace on the chart was started at the beginning of the control flow period. The contents of the beaker were weighed to calculate the flow rate. Once the control beaker was moved out of intercept position, the flow would fall into the raingage beaker. This flow would be continued for a period of generally 1 to 2 hours and called "test flow." Every thirty minutes the drip rate was recorded. Room temperatures and time were also recorded.

While the test flow continued into the raingage beaker, the contents of the control beaker were weighed. After cleaning and re-weighing the control beaker it was returned to the swivel support for the next control check. After a second control intercept was taken (usually for 30 minutes), a second control flow rate was calculated. The test flow rate for the interval of time that the feed entered the raingage beaker was calculated as an average of the two control flows before and after the test flow period, respectively.

Most tests were started before 09:00 MST and generally continued for 5 to 8 hours. Once a test had ended, the beginning and ending points of "test flow" and "control flow" periods were marked on the chart, and the chart trace read. In all cases, chart readings were carefully estimated to the nearest 0.005 inch. Then the control flow rates were calculated and the expected chart trace plotted with time. This was done to prevent

Table 1. Calibration of the Belfort Raingages (inches of water)

Date	Ideal Level	GAGE # 7936 Chart Reading	7936 Deviation	7730 Chart Reading	7730 Deviation	7723 Chart Reading	7723 Deviation
6 October 1982	0.000	-.005	-.005	0.010	+.010	0.000	0
	1.000	.995	-.005	1.010	+.010	1.000	0
	2.000	1.990	-.010	2.015	+.015	2.000	0
	3.000	2.990	-.010	3.075	+.015	3.005	+.005
	4.000	4.000	0	4.010	+.010	4.005	+.005
	5.000	5.000	0	5.005	+.005	5.005	+.005
	6.000	6.000	0	6.010	+.010	6.010	+.010
	7.000	6.995	-.005	7.010	+.010	7.005	+.005
	8.000	8.005	+.005	8.005	+.005	8.010	+.010
	9.000	9.030	+.030	9.010	+.010	9.010	+.010
	10.000	10.010	+.010	10.010	+.010	10.015	+.015
	11.000	11.000	0	11.010	+.010	11.015	+.015
	12.000	11.990	-.010	12.010	+.010	12.010	+.010
8 November 1982	0.000	-.010	-.010	0.000	0.000	-.010	-.010
	1.000	.990	-.010	1.010	+.010	1.035	+.035
	2.000	1.970	-.030	2.020	+.020	2.035	+.035
	3.000	2.970	-.030	3.015	+.015	3.000	0
	4.000	3.970	-.030	3.990	-.010	4.000	0
	5.000	4.990	-.010	5.005	+.005	5.020	+.020
	6.000	5.985	-.015	5.895	-.105	5.980	-.020

bias in reading the charts which might have resulted with foreknowledge of the actual flow rates. A daily test period was considered to commence with the beginning of the first control period and conclude with the end of the last control period of that day. The chart data were then plotted on the same graph as the test flow data for comparison purposes. After all chart readings were complete, the total catch within the raingage beaker was weighed and plotted on the respective graph to compare with the observed final chart level and with the final level estimated from the control flow data. These plots appear in Appendix A as Figures 4 to 18. During the test periods, air temperatures recorded adjacent to the gages usually ranged between 30° and 60° F. Most tests were conducted at temperatures above freezing.

V. Results

Data collected from the testing program were reduced and analyzed to determine the accuracy that can be obtained from the gages. The effort was subdivided into four separate areas of investigation to isolate and quantify potential sources of error, and to determine accuracies possible at short- and long-time scales. These results will be discussed below.

1. Chart reading accuracy.

A portion of the recorded data was independently reduced by two analysts to determine the resolution and accuracy obtainable during the manual data reduction process. Both persons worked from photocopies of the original record and made readings at identical times on charts. The results indicated that the independent readings agreed to within 0.005 inch of each other over 95 percent of the time. Only one case occurred where the difference was as much as 0.015 inch. It must be noted, however, that the sample size was small (22 points), there was no pressure to make the readings quickly, and the analysts understood that their readings would be compared. Thus, it is not realistic to expect that routine reduction of large amounts of data would achieve this level of accuracy. It is probable that chart reading variations will introduce a ± 0.01 inch or greater error in the data under normal circumstances.

2. Gage chart fluctuations with no precipitation input.

Two tests were conducted to determine if fluctuations in the chart record occurred during periods when no precipitation was entering the gage. The tests were done by operation of the chart drives over a period of approximately 20 hours while the gage buckets were completely empty except for the metal calibration weight used to bring the pen trace above the zero line on the chart. During the test period, the temperature was relatively constant, ranging between 44° and 50° F.

Table 2. Universal Recording Raingage Test Schedule

	Date (1982)	Test No.	Gage No.	Start Time (MST)	Stop Time (MST)
1	15 November	319-1B	7730	0835	1705
2		319-1C	7723	0835	1712
3	16 November	320-1A	7936	0830	1315
4		320-1B	7730	0830	1315
5	18 November	322-1A	7936	0830	1630
6		322-1B	7730	0830	1630
7	19 November	323-1A	7936	1022	1615
8	22 November	326-1A	7936	0840	1500
9		326-1B	7730	0840	1500
10	23 November	327-1A	7936	0830	1630
11		327-1B	7730	0830	1630
12	29 November	333-1A	7936	0900	2315
13		333-1B	7730	0900	2315
14	30 November	334-1A*	7936	1545	1110(1 Dec)
15		334-1B*	7730	1545	1110(1 Dec)

*Test conducted to measure fluctuations with zero flow into the gage.

Test results showed definite fluctuations in both gages, with maximum departures from the starting point of 0.010 and 0.015 inch respectively. These are illustrated in Figures 17 and 18 in Appendix A. The departures were in opposite directions for the two gages; one gage showed an increase from the starting point at about the halfway point in the test. After that time, the traces gradually converged towards the starting point. Both units were within 0.005 inch of the initial point at the end of the test period. The source of these deviations is unknown but it is apparent that precipitation totals from storm events of one-half day or longer duration could be subject to errors of approximately 0.01 inch if these gages are typical.

3. Storm total accuracy.

Each of the tests in which simulated precipitation was added to the beaker within the gage bucket allowed a precise comparison between the "true" catch and that indicated on the chart record. The collection beaker (with evaporation suppressant) was weighed to the nearest 0.1 g before each trial, and then re-weighed with the collected water after the conclusion of each day's tests. Tests conducted before gage trials disclosed that for the evaporation suppressant and beakers used, evaporation losses were negligible over time periods far exceeding those between weighings. Thus, any discrepancies between the weighed accumulation in the beakers and the chart readings are not due to evaporation.

In the initial tests the rise in the chart trace seemed to lag behind that expected from the calculated input flow rate. This suggested that perhaps hysteresis was occurring in the gage mechanism. Consequently, with most later tests (beginning on 18 November 1982) the chart cylinders were not removed from the drives and the collection beakers were not taken from the buckets and weighed until the morning after the final test flow was ended. This allowed more time for the hysteresis to correct itself. In addition, just before the beaker and the chart were removed, the gage bucket platform was tapped with a pencil to remove any remaining frictional drag in the mechanism.

The indicated chart levels were then determined for the following times: (1) at the immediate end of simulated precipitation input; (2) after several hours of zero precipitation input; and (3) after the mechanism was tapped. Results are presented in Table 3. It can be seen that, on the average, the gages consistently undermeasured for all three measurement times. The average undermeasurement at the point simulated precipitation input was ended was 0.017 inch. The data suggest that the error increases with total precipitation amount, but additional trials would be required to confirm this. This level of accuracy is quite impressive, as it implies that the basic gage is capable of providing

precipitation totals for 3- to 11-hour storms accurate to about the nearest 0.02 inch for an 8-inch orifice. Larger orifice gages, as often used to measure snowfall, would yield even better accuracy with the same gage mechanism.

The storm total accuracy could be improved, in any event, if the final chart reading were made as far after the end of the storm as possible. Table 3 shows that the average undermeasurement was approximately halved when the final measurement was made 9 to 16 hours following the end of the precipitation. It would not always be possible to do this in an actual field situation where frequent storm events occurred. An additional problem would be that the lag would also tend to obscure the actual ending time of precipitation.

The results are even better when the gage is subjected to an outside mechanical disturbance before the storm totals are read. The average error was reduced to almost zero when the chart readings were made after the platform was tapped with a pencil. The small tap with the pencil did not significantly displace the gage mechanism and may replicate rather well a bit of wind disturbance on the gage. This is not to suggest that gages be preferentially operated in areas subject to wind action, as the gage inaccuracies due to wind effects are well documented and far greater than those discussed here.

4. Short term accuracy.

It may be desirable to analyze the results of cloud seeding efforts on a time scale less than that of the total storm duration. Hourly precipitation data, for example, could be beneficial if sufficiently accurate. The gage accuracies for precipitation events of between 1- and 3-hour duration were estimated from the control flow rate data. As described previously, the experimental design incorporated a second set of beakers which could be swung into place to intercept the test flow to the gage. These control flows (usually of one-half-hour duration) were used as a check to insure that the simulated precipitation rate being added to the gage remained approximately constant with time. Each day's test was started with an intercepted "control flow" measurement. At the conclusion of this period, the control beaker was removed, allowing the flow to enter the test beaker within the gage bucket. The test flow was maintained for a period ranging from approximately 1- to 3-hours, after which another half-hour control flow sample was normally taken. The test would continue in this alternating manner for the remainder of the day with all test flow precipitation accumulating in the gage.

To estimate the accuracy of the gages in measuring each of the 1- to 3-hour-duration increments, the control flow rates before and after each test flow period were averaged. The average rate was used to estimate the amount of precipitation which should have fallen into the gage for that particular test flow period. This estimate was compared with the chart total from readings at the beginning and end of each test flow period. This procedure was applied to all 58 available test flow periods. The bulk of the data (72 percent) consisted of 1-hour control samples, while the 1.5-, 2.0-, and 3.0-hour samples comprised 17, 7, and 4 percent of the data, respectively. Inspection of the data (presented in Appendix 2) shows that in most instances control flow rates were quite consistent from one period to the next. In approximately 78 percent of the cases, the flow rate deviated by less than 10 percent from control flow period to the next. A few cases exhibited substantial changes because control flow rates were deliberately altered by 100 percent. However, the flow system was never tampered with or adjusted during a test flow period. At any rate, it is noteworthy that even in the instances of altered control flow, the departures between the precipitation estimated from the averaged control flows and that indicated on the chart was not obviously larger than those observed when flow rates were very consistent. This suggests that any changes in flow rate were well represented by averaging.

Results, shown in Figure 3, indicate that in almost 40 percent of the cases the chart response was within -0.003 to -0.007 inch of the estimated input. The estimated 1-hour control input amounts ranged from 0.009 to 0.109 inch with a mean of 0.051 inches. The 1.5-hour data (9 cases) ranged from 0.042 to 0.067 inches with a mean of 0.060 inches. Four 2.0-hour blocks had a mean of 0.070 inches with a range of 0.038 to 0.101 inches while the two 3-hour cases were 0.041 and 0.120 inches.

A tabulation of the data contained in Appendix 2 indicated that in 54 percent of the cases the chart response was within ± 10 percent of the input as estimated from the control flow data. In 91 percent of the cases, the chart response was within ± 30 percent of the estimated input, and in 97 percent of the cases, it was within ± 50 percent. This is remarkable performance considering the simulated precipitation amounts ranged from about 0.01 to 0.12 inches, that is, considering that only small storm amounts were simulated.

Figure 3. Distribution of departures between control flow estimates and chart amount estimates.

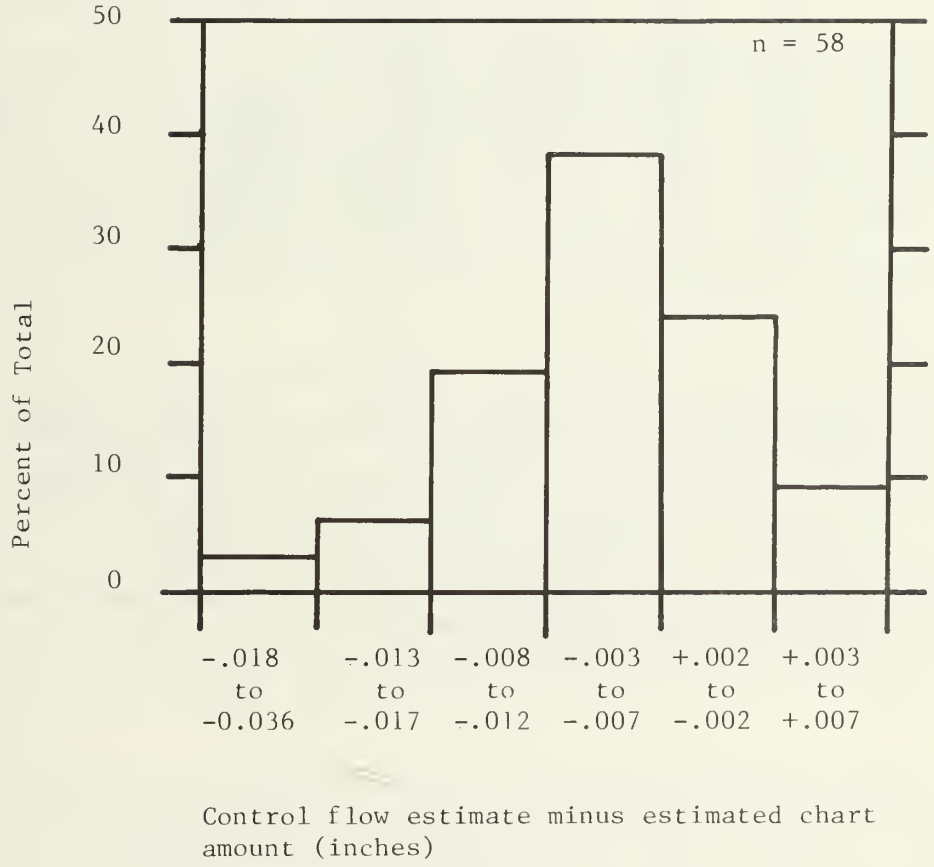


Table 3. Weighed amounts of precipitation caught in the gages compared to indicated amounts on the chart.

Text No.	Hours of input to gage (a)	Ave. input rate (in/hr) (b)	Weighed precip. in gage (in) (c)	Chart precip. at end of test flow (in)	Difference (d)	Chart precip. after waiting period (in)	Waiting period (hr)	Difference (d)	Chart precip. after tapping (in)	Difference (d)
319-1B	5.5	.048	.266	.238	-.028					
314-1C	5.5	.028	.156	.135	-.021					
320-1A	3	.022	.065	.055	-.010					
320-1B	3	.047	.140	.128	-.012					
322-1A	5	.024	.120	.105	-.015	.115	14	-.005	.125	+.005
322-1B	5	.081	.407	.395	-.012					
323-1A	4	.025	.100	.110	+.010					
326-1A	4	.102	.407	.390	-.017	.400	15	-.007	.405	-.002
326-1B	4	.040	.159	.145	-.014	.145	15	-.014	.150	-.009
327-1A	5	.087	.436	.415	-.021	.430	16	-.006	.430	-.006
327-1B	5	.093	.466	.425	-.041	.435	16	-.031	.455	-.011
333-1A	11	.042	.462	.455	-.007	.465	9	+.003	.470	+.008
333-1B	11	.027	.298	.270	-.028	.290	9	-.008	.305	+.007
Average departures of chart readings from weighed amounts +					-.017			-.010		-.001

(a) Includes only the time during which test flow was flowing into the gage.

(b) Calculated by division of weighed amount in gage by the hours of input.

(c) Weighed at the immediate end of the test flow period.

(d) Negative (positive) values signify indicated chart amounts are less than (greater than) weighed amounts.

IV. Summary and Conclusions

The results of the laboratory tests that have been presented appear to support the following conclusions concerning the Belfort weighing precipitation gages used.

Over periods of several hours, chart readings generally indicated less precipitation than the measured simulated amount dripped into the gages. The mean departure was approximately 0.02 inches with the largest departure 0.04 inches. These departures were somewhat reduced by passage of time after simulated precipitation, and markedly reduced by tapping of the mechanism. Apparently some hysteresis existed in the mechanical weighing mechanism. However, it was usually limited to 0.01 to 0.03 inches precipitation equivalent.

Over periods of 1- to 3-hours, chart readings generally under-estimated the simulated precipitation amounts, which ranged from 0.001 to 0.12 inches. Almost 40 percent of the cases were within -0.007 to -0.003 inches of the estimated amounts entering the gages, while 81 percent were within -0.012 to +0.002 inches. On a percentage basis, 54 percent of the cases had a chart response within ± 10 percent of the estimated simulated precipitation amount, and 91 percent of the cases were within ± 30 percent.

This is considered remarkable performance in view of the various errors possible. These include errors in reading the charts (usually within 0.005 inch with the considerable care taken), long-term drift of the mechanism (ranging over as much as 0.015 inch in the two 20-hour tests), mechanical hysteresis, and probably other sources of error not considered such as expansion/contraction of the chart paper due to changes in temperature and humidity. In addition, errors were possible in weighing the total simulated precipitation for the few- to several-hour tests, and in estimating the test flow amounts in the 1- to 3-hour tests, particularly where the flow rate varied with time.

In summary, the results of the tests presented suggest that the Belfort weighing gages, when carefully calibrated and with care given to manually reading the charts, can provide accurate precipitation data with low precipitation rates of 0.01 to 0.10 inch per hour. Errors should be limited to approximately 0.01 to 0.03 inch in most cases, and this could be reduced with an orifice larger than the standard 8-inch-diameter orifice (as is often needed to minimize gage capping when measuring snowfall).

A note of caution is in order; it was not practical to conduct many tests at below freezing temperatures because of unusually warm weather during the tests. It would be worth repeating the tests at colder ambient temperatures to determine whether accuracy is further degraded (e.g. increased hysteresis).

Unless further testing at colder temperatures revealed significantly greater errors, it would appear that the errors inherent in the Belfort gages tested were far less significant than those expected in the field due to other causes such as unrepresentative gage sites and wind-related undercatch.

APPENDIX A

Plotted Data for Individual Tests

Figure 4. Precipitation gage test 319-1B

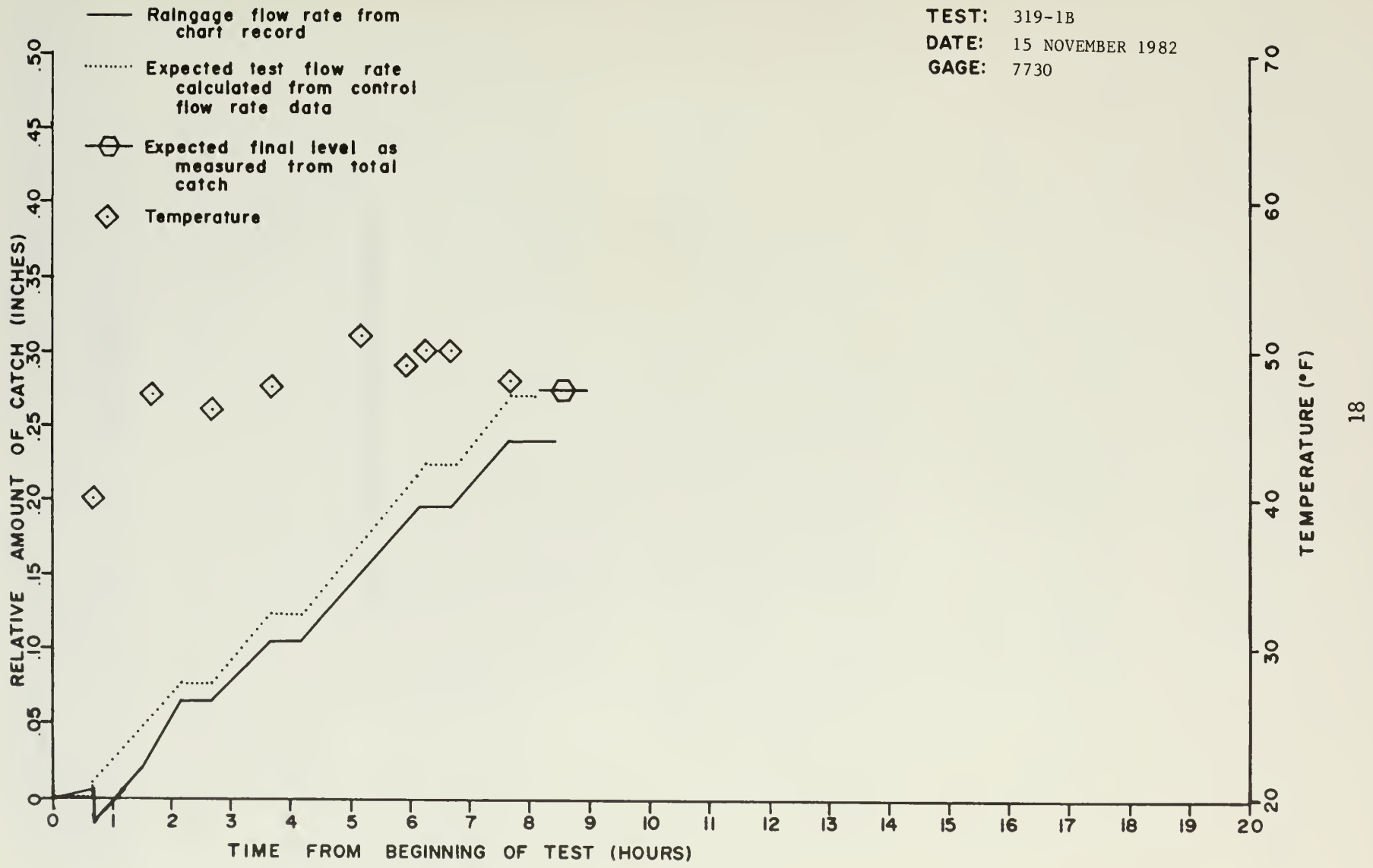

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 319-1B
DATE: 15 NOVEMBER 1982
GAGE: 7730
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 5. Precipitation gage test 319-1C

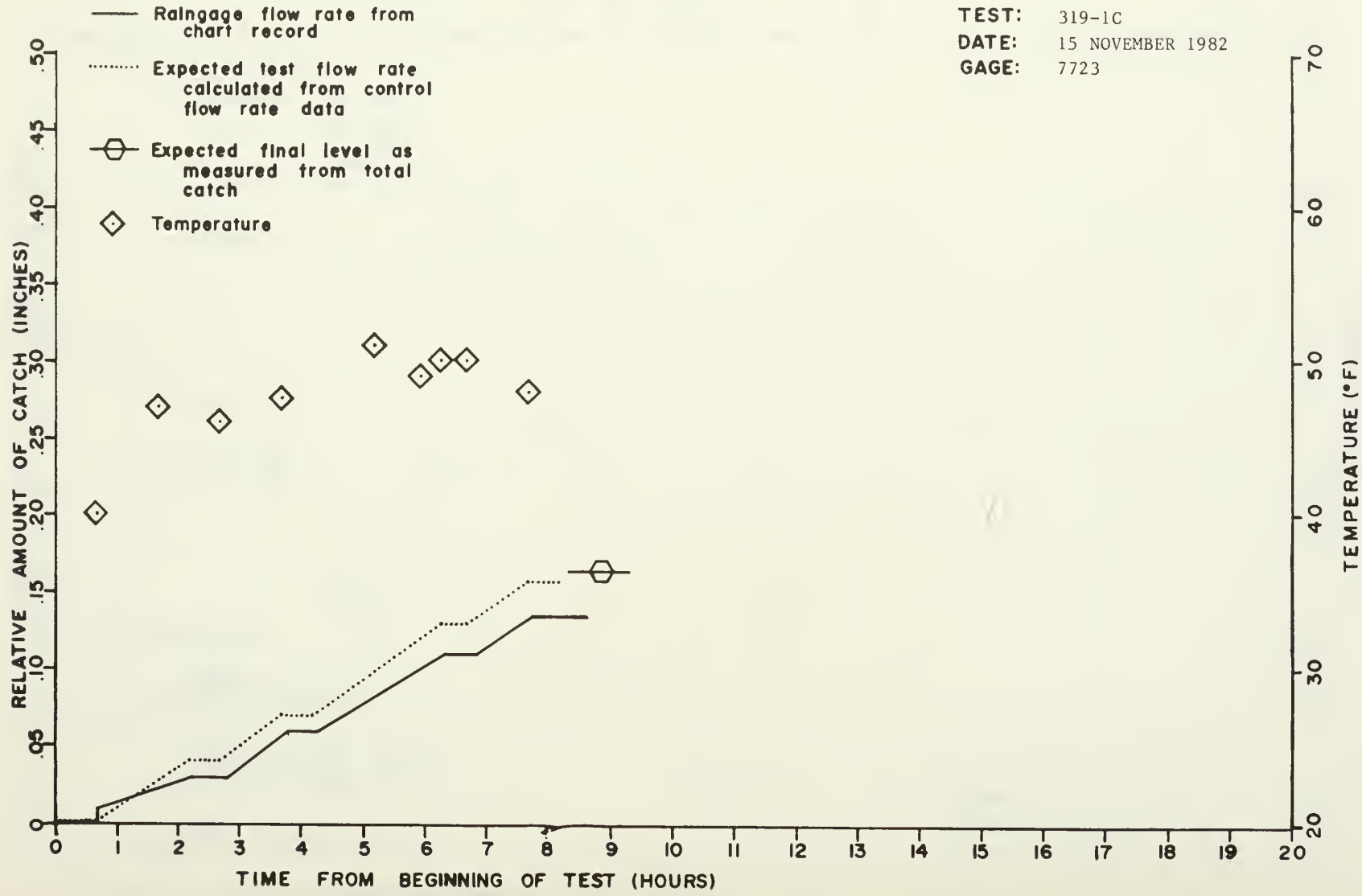

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 319-1C
DATE: 15 NOVEMBER 1982
GAGE: 7723
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 6. Precipitation gage test 320-1A

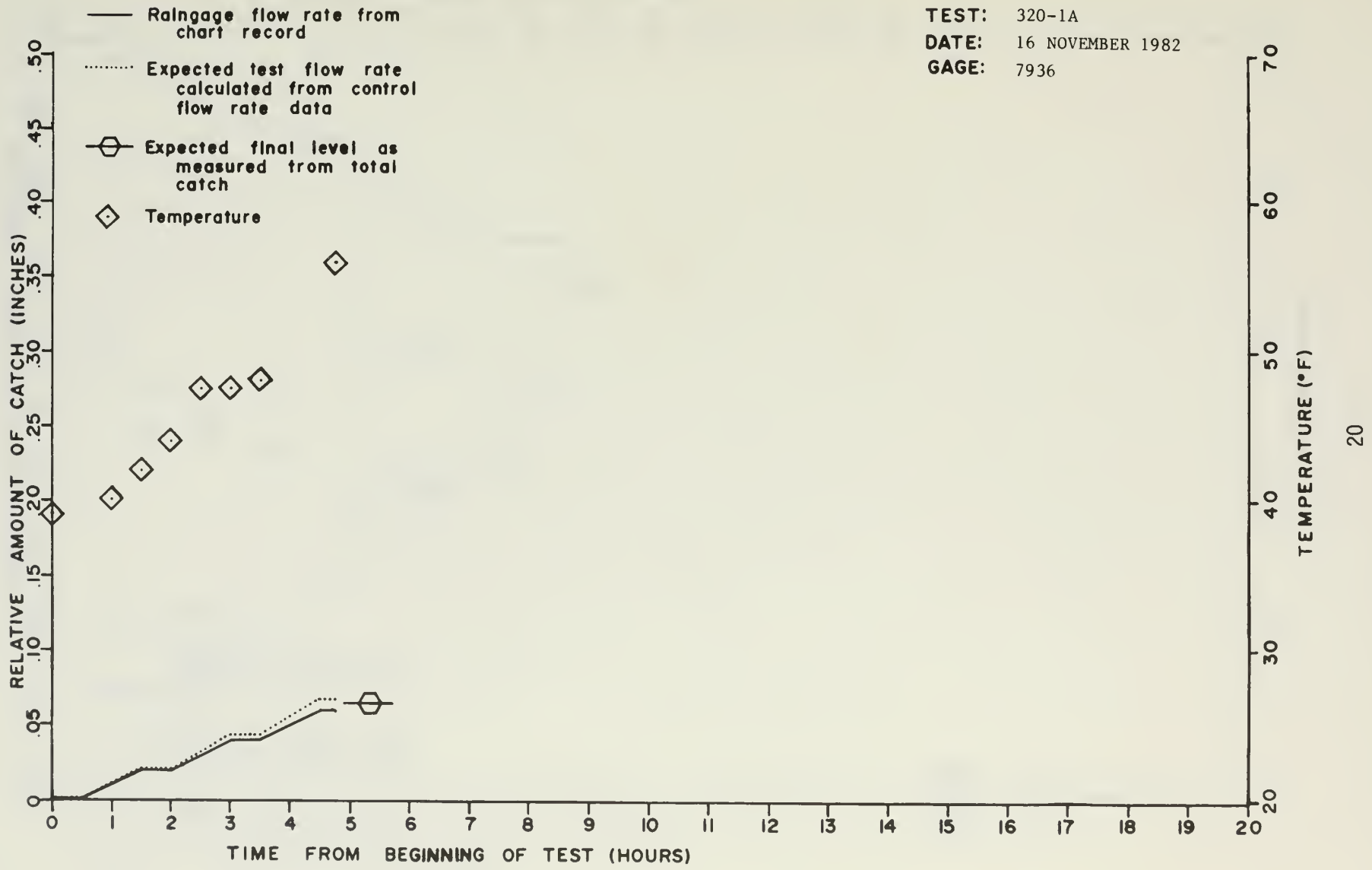

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 320-1A
DATE: 16 NOVEMBER 1982
GAGE: 7936
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 7. Precipitation gage test 320-1B

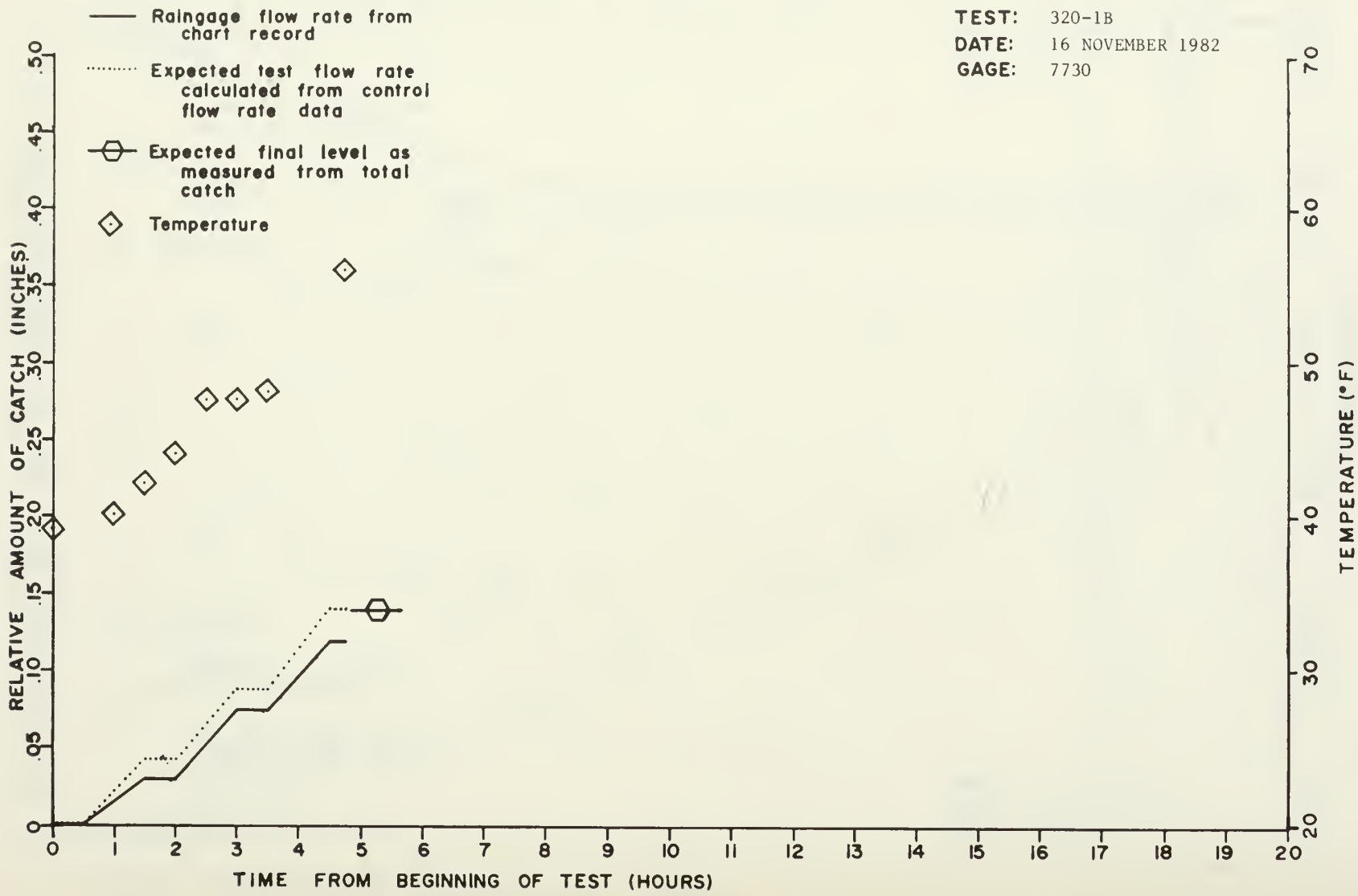


Figure 8. Precipitation gage test 322-1A

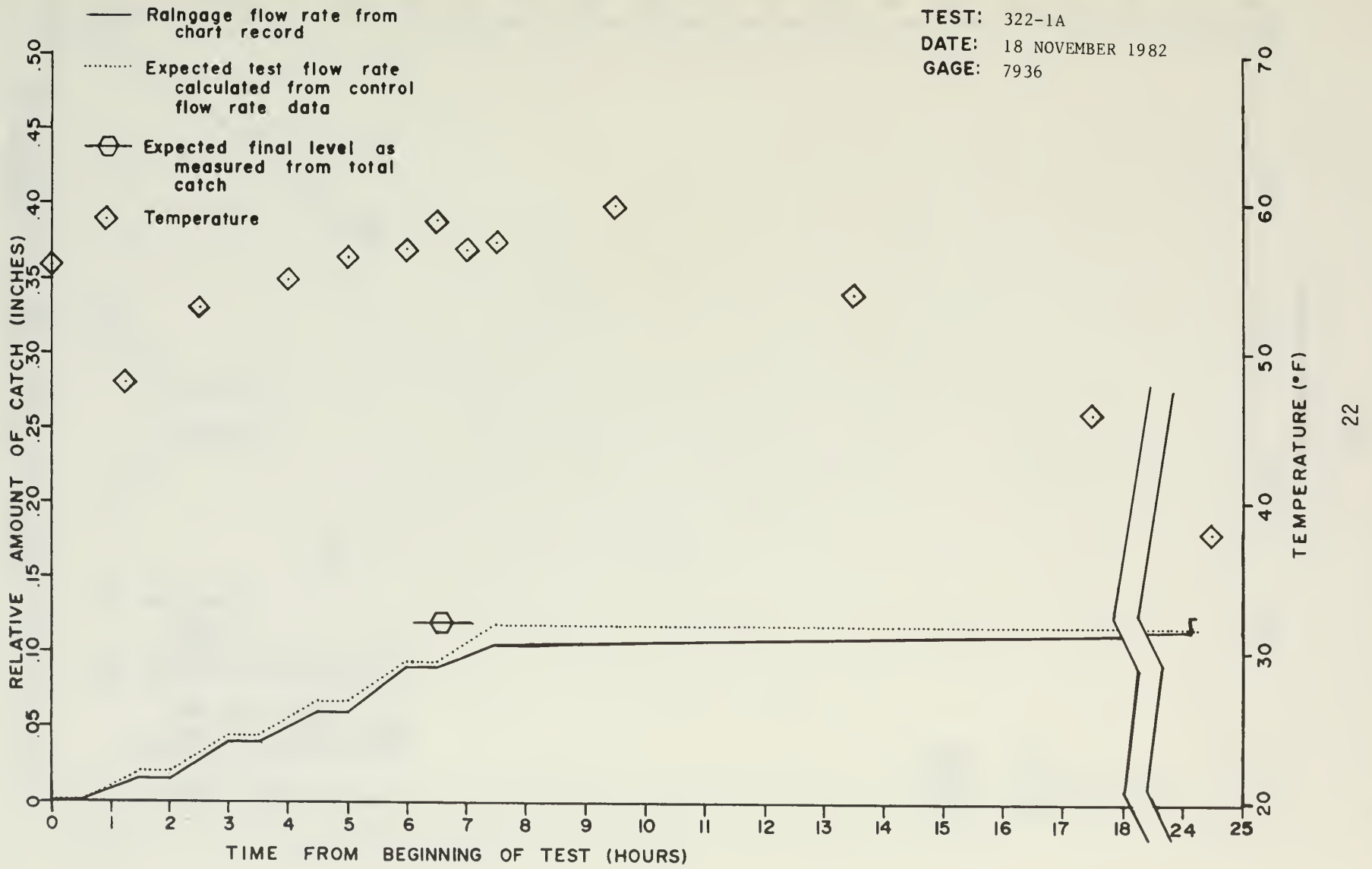

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 322-1A
DATE: 18 NOVEMBER 1982
GAGE: 7936
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 9. Precipitation gage test 322-1B

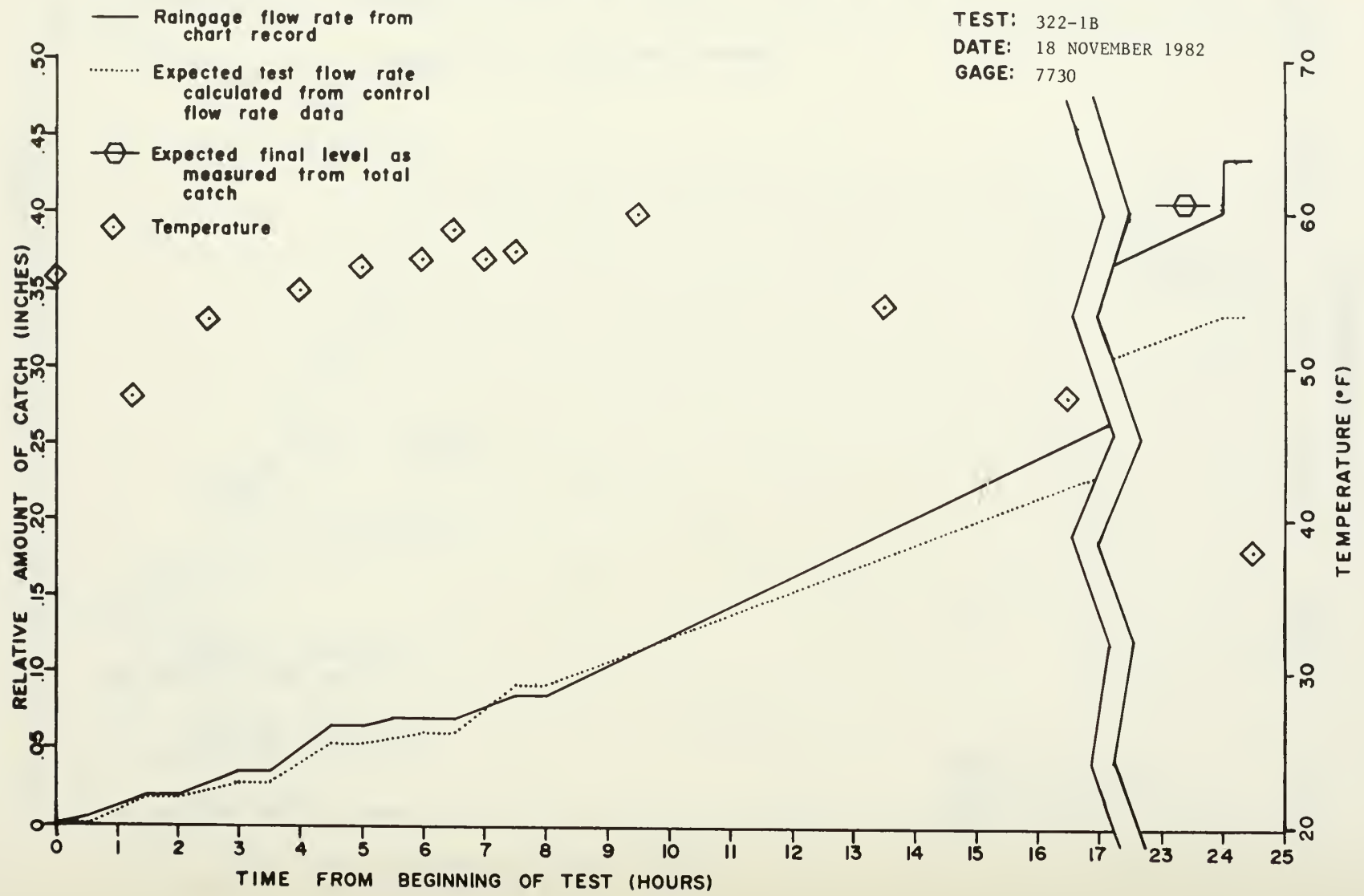

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 322-1B
DATE: 18 NOVEMBER 1982
GAGE: 7730
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 10. Precipitation gage test 323-1A

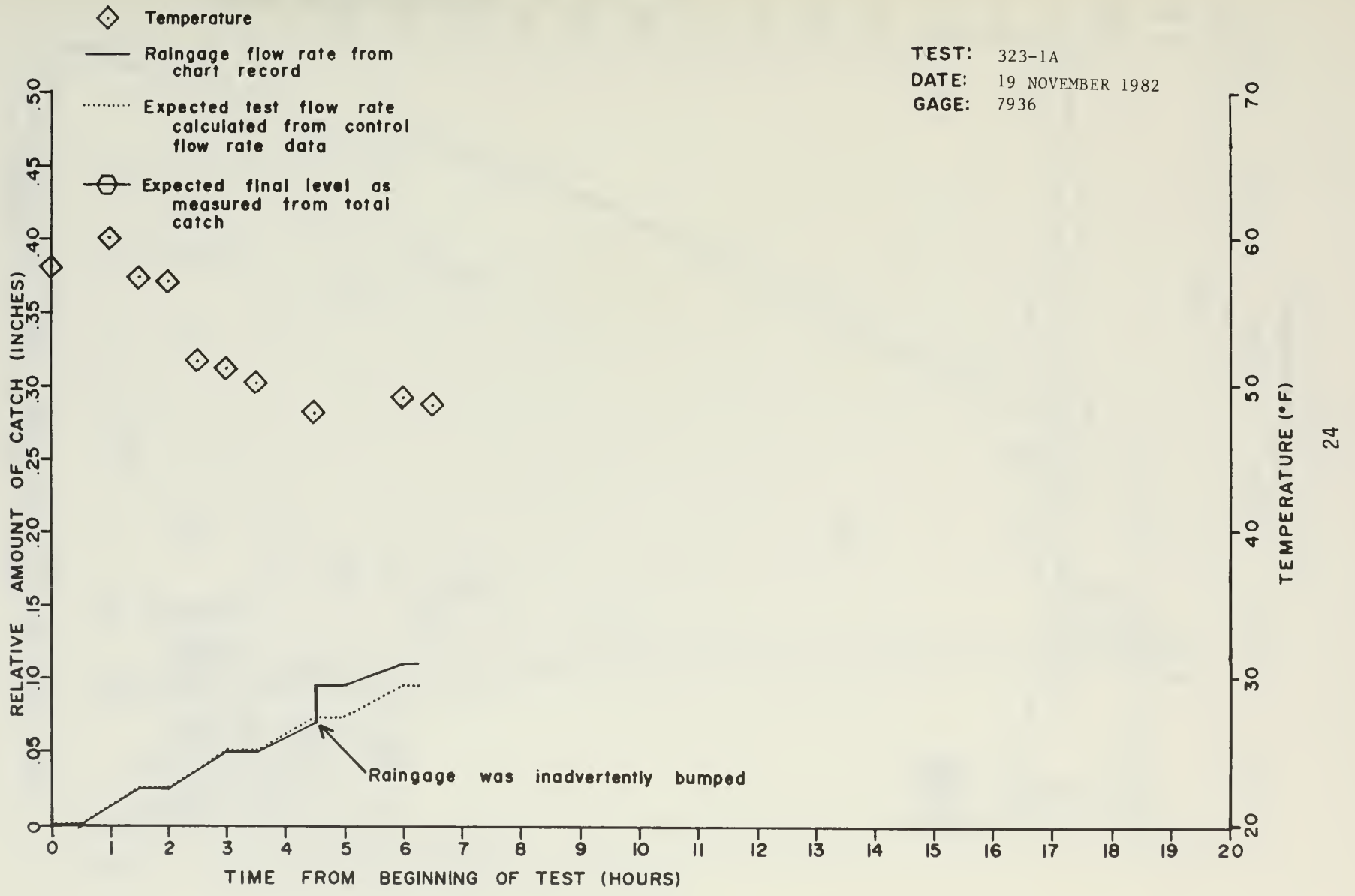

Temperature
Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
TEST: 323-1A
DATE: 19 NOVEMBER 1982
GAGE: 7936
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)
Raingage was inadvertently bumped

Figure 11. Precipitation gage test 326-1A

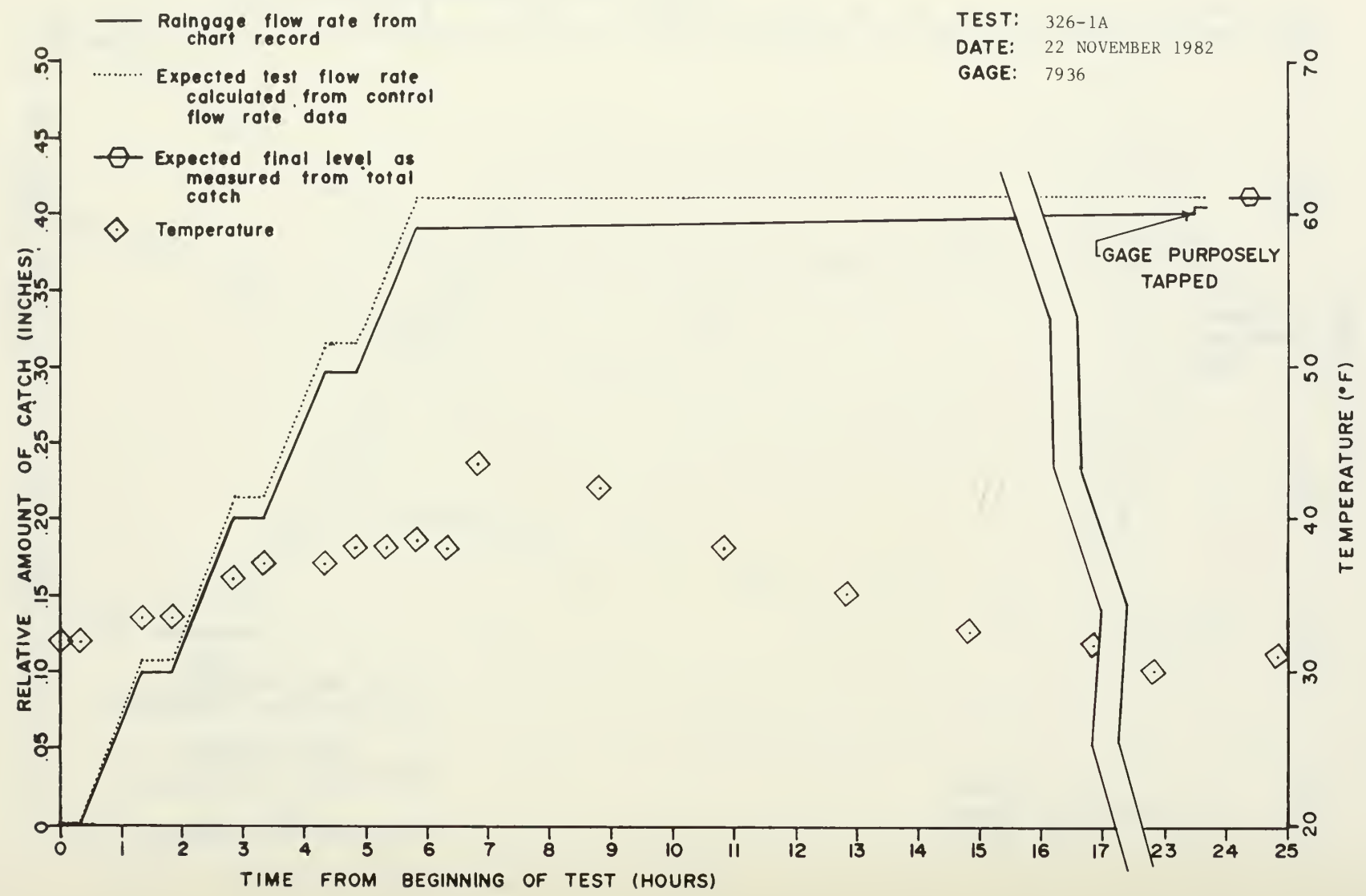

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 326-1A
DATE: 22 NOVEMBER 1982
GAGE: 7936
GAGE PURPOSELY TAPPED
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 12. Precipitation gage test 326-1B

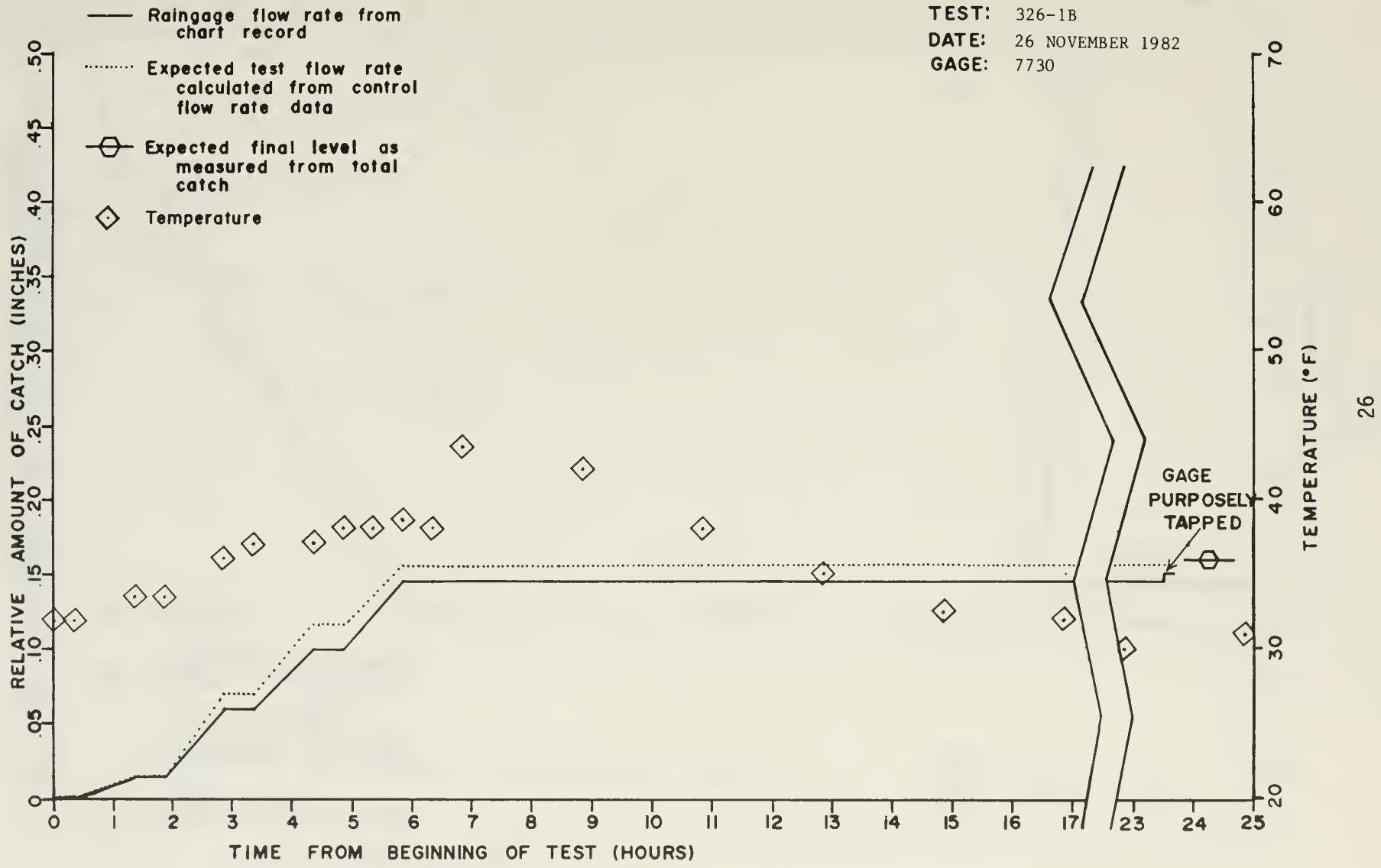

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 326-1B
DATE: 26 NOVEMBER 1982
GAGE: 7730
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)
GAGE PURPOSELY TAPPED

Figure 13. Precipitation gage test 327-1A

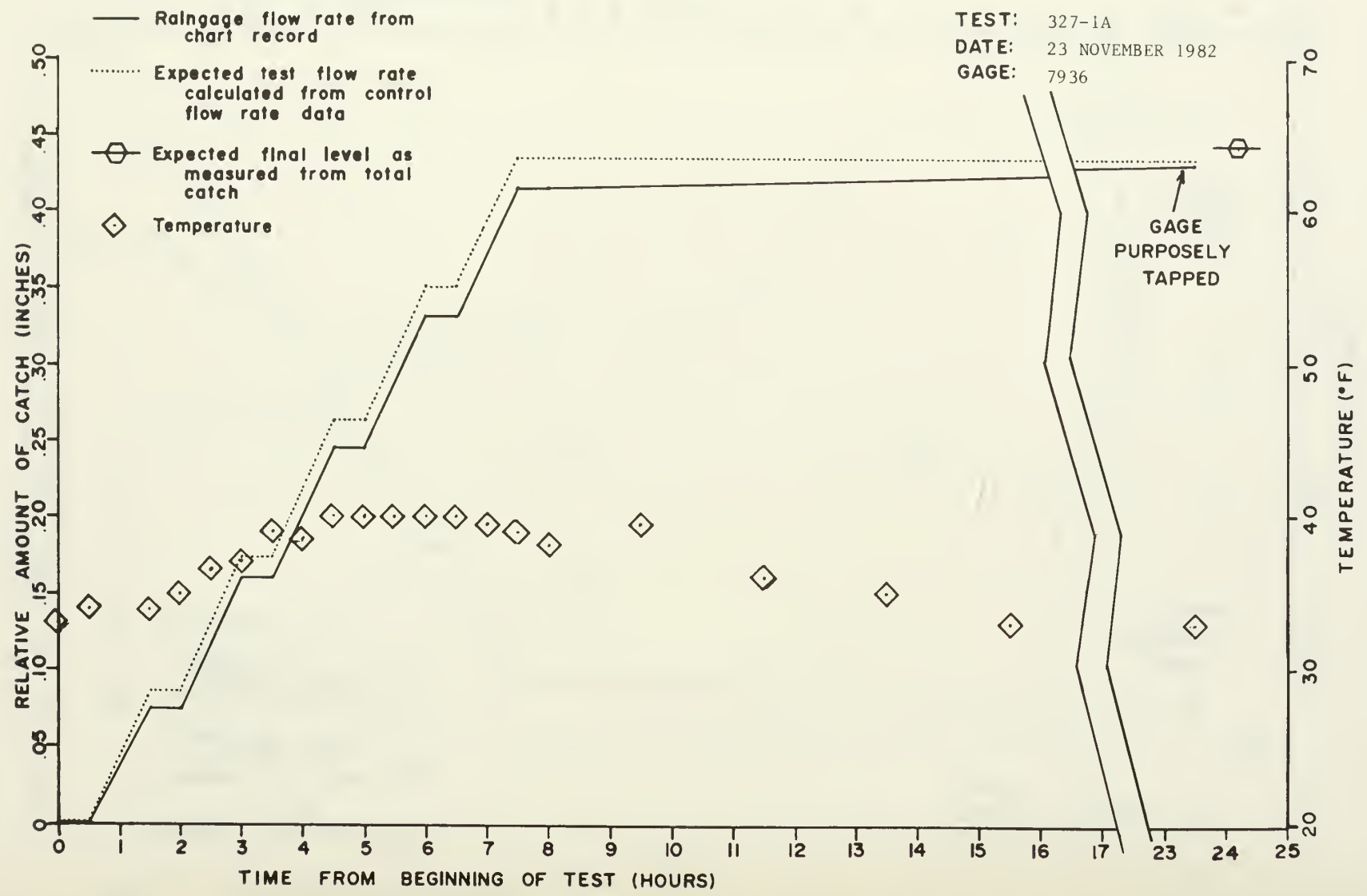

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 327-1A
DATE: 23 NOVEMBER 1982
GAGE: 7936
GAGE PURPOSELY TAPPED
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 14. Precipitation gage test 327-1B

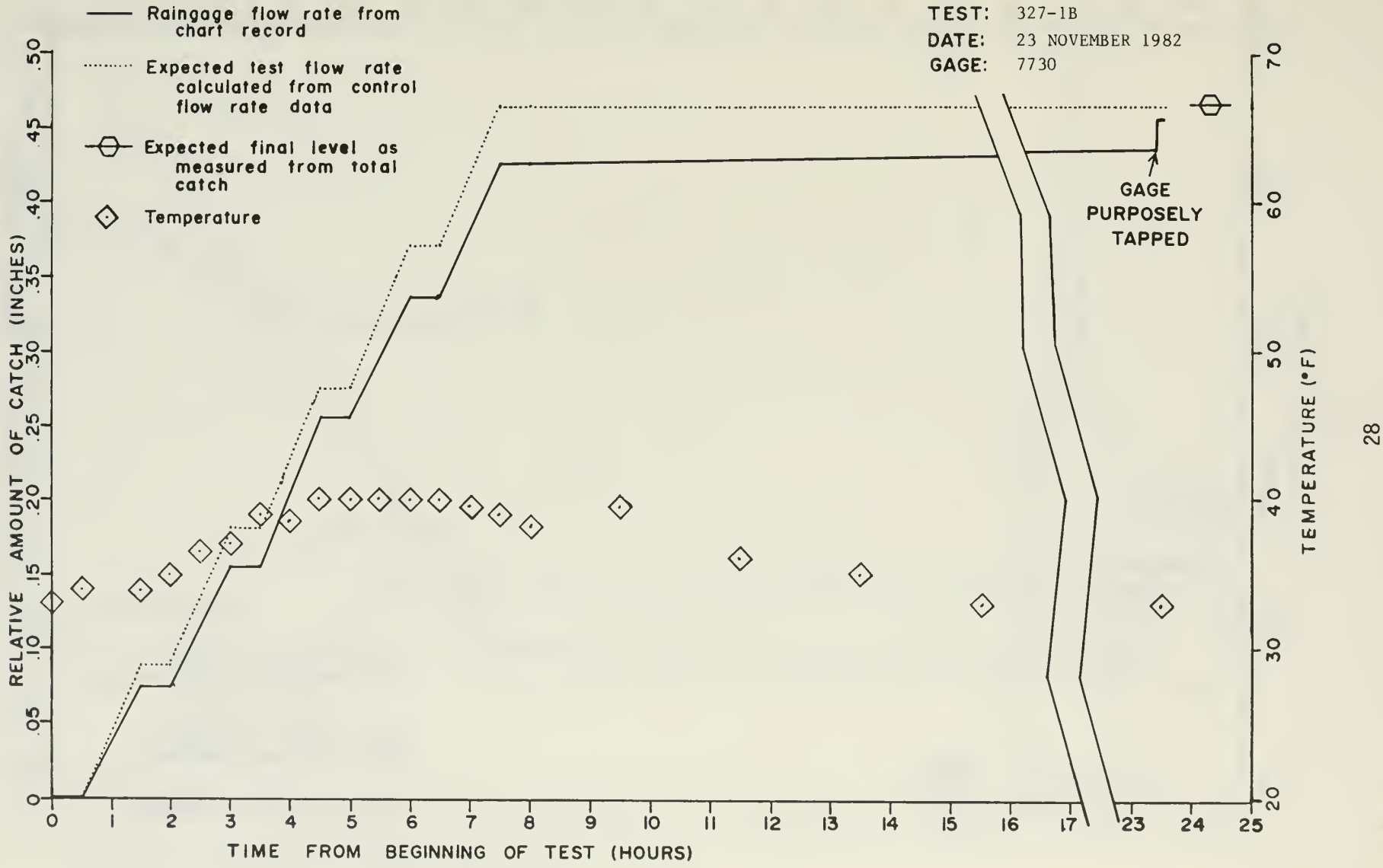

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 327-1B
DATE: 23 NOVEMBER 1982
GAGE: 7730
GAGE PURPOSELY TAPPED
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 15. Precipitation gage test 333-1A

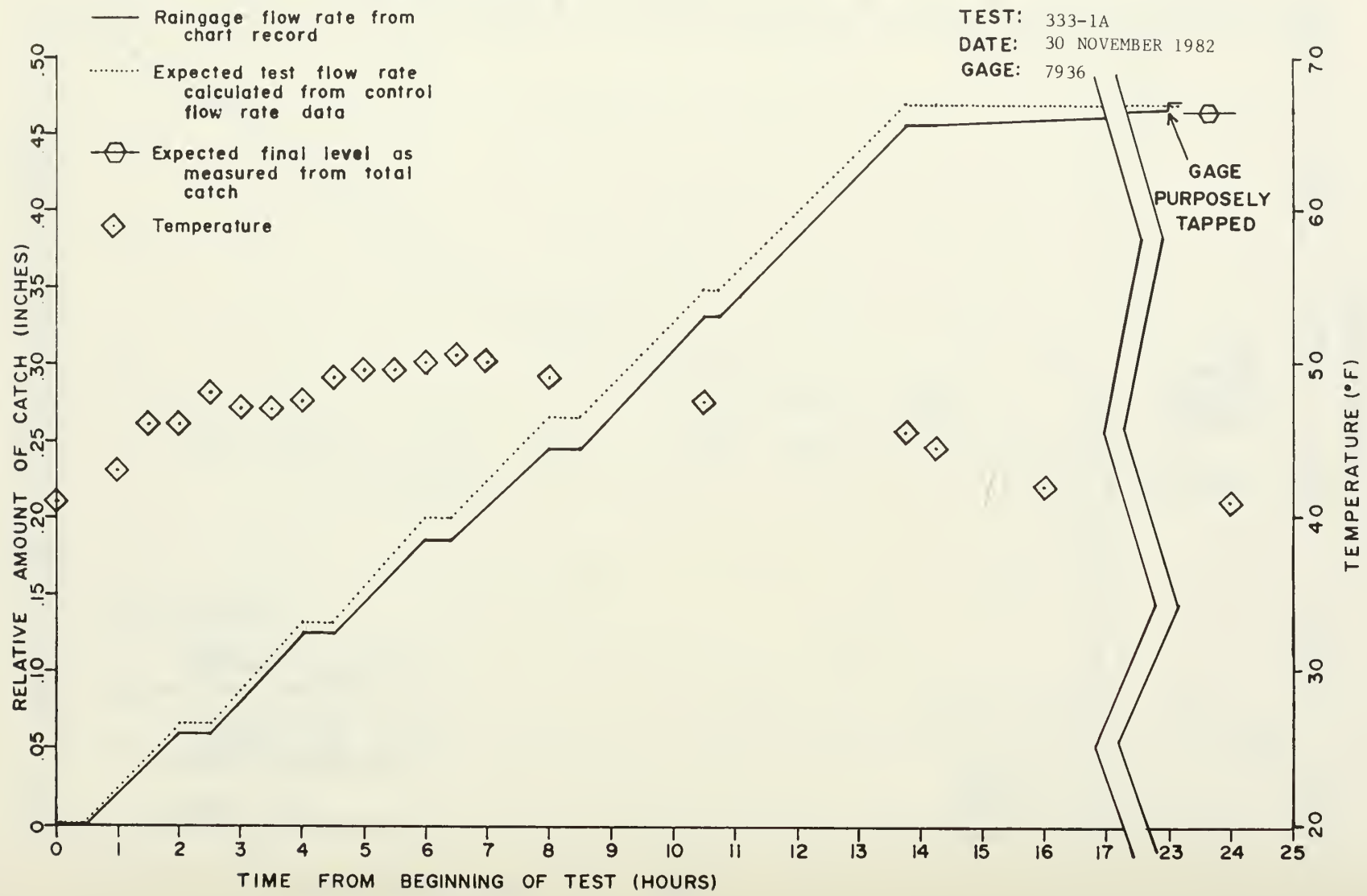

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 333-1A
DATE: 30 NOVEMBER 1982
GAGE: 7936
GAGE PURPOSELY TAPPED
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 16. Precipitation gage test 333-1B

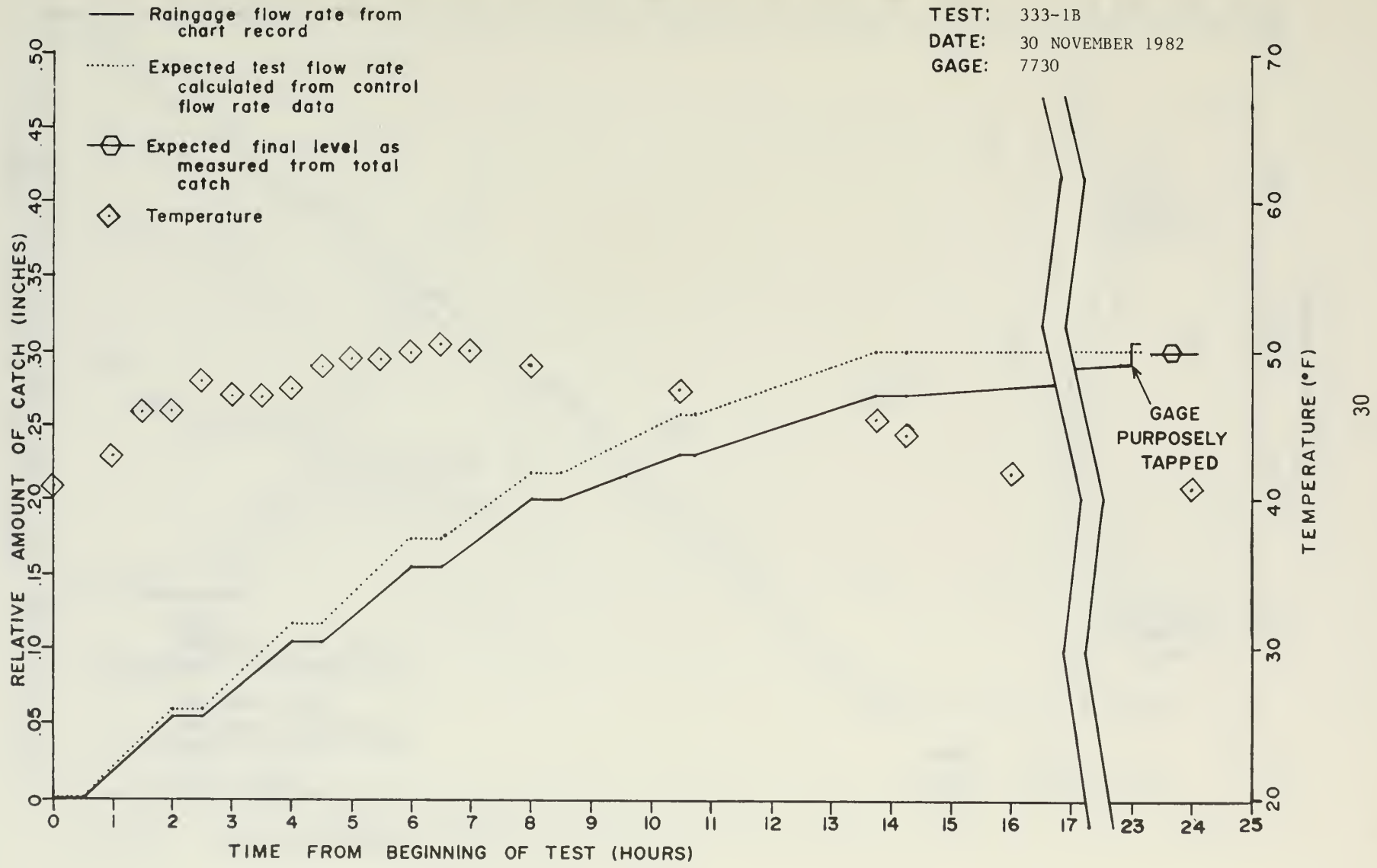

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 333-1B
DATE: 30 NOVEMBER 1982
GAGE: 7730
GAGE PURPOSELY TAPPED
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)

Figure 17. Precipitation gage test 334-1A

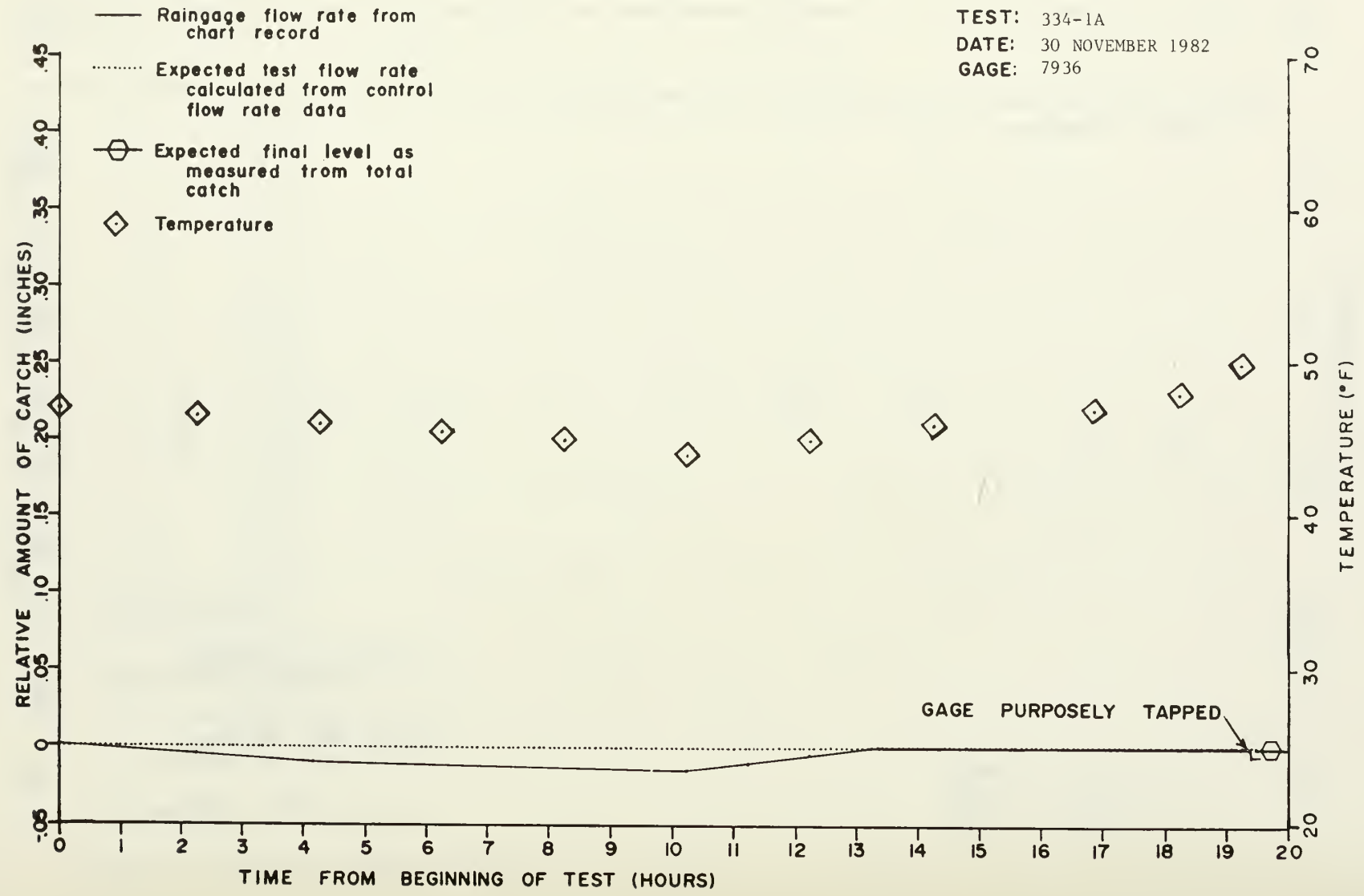
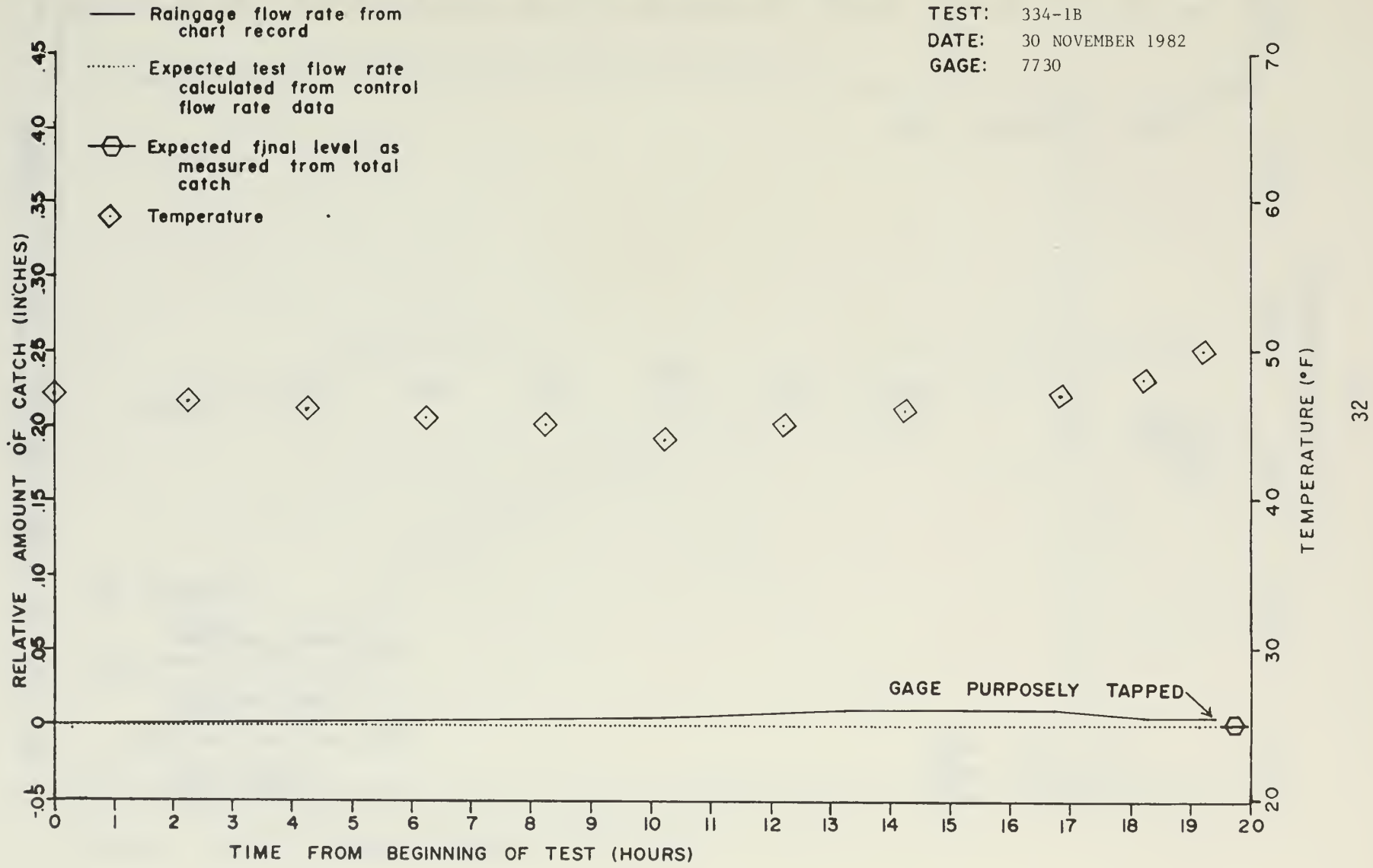

Raingage flow rate from chart record
Expected test flow rate calculated from control flow rate data
Expected final level as measured from total catch
Temperature
TEST: 334-1A
DATE: 30 NOVEMBER 1982
GAGE: 7936
RELATIVE AMOUNT OF CATCH (INCHES)
TEMPERATURE (°F)
TIME FROM BEGINNING OF TEST (HOURS)
GAGE PURPOSELY TAPPED

Figure 18. Precipitation gage test 334-1B



APPENDIX B

Comparison of Chart Recorded Precipitation Amounts versus Inputs Estimated from Control Flow Data

Comparison of chart recorded precipitation amounts vs inputs estimated from Control Flow Data.

Date/ Test No.	CONTROL FLOW DATA			CHART DATA			Estimated precipitation Control Flow (Ave. rate)x duration	Estimated precip. from chart	- =chart under + =chart over
	Time Period	Flow Rate (in/hr)	Ave. Flow Rate (in/hr)	Time	Chart Level (in)	Test duration (hr)			
15 Nov. 82 319-1B	0835-0915	.042		0915	1.225				
	1045-1115	.047	.0445	1045	1.285	1.5	.067	.060	-.007
	1215-1245	.048	.0475	1115 1215	1.285 1.325	1.0	.048	.040	-.008
	1445-1515	.049	.0485	1245 1445	1.325 1.415	2.1	.101	.090	-.011 -.007
	1615-1645	.046	.0475	1515 1615	1.415 1.46	1.0	.048	.045	-.003
15 Nov. 82 319-1C	0835-0915	.026		0915	1.27	1.5			
	1045-1115	.030	.028	1045	1.31	1.5	.042	.040	-.002
	1215-1245	.028	.029	1115 1215	1.31 1.33	1.0	.029	.020	-.009
	1450-1515	.029	.0285	1245 1450	1.33 1.38	2.1	.059	.050	-.009
	1615-1645	.027	.028	1515 1615	1.38 1.405	1.0	.028	.025	-.003
16 Nov 82 320-1A	0830-0900	.020	.0211	0900	1.47	1.0			
	1000-1030	.022	.0211	1000	1.49	1.0	.021	.020	.001
	1130-1200	.023	.0211	1030 1130	1.49 1.51	1.0	.022	.020	-.002
	1300-1315	.025	.024	1200 1300	1.51 1.53	1.0	.024	.020	-.004
16 Nov 82 320-1B	0830-0900	.04	.0425	0900	1.49	1.0			
	1000-1030	.045	.0425	1000	1.52	1.0	.0425	.03	-.013
	1130-1200	.047	.046	1030 1130	1.52 1.565	1.0	.046	.045	-.001
	1300-1315	.056	.052	1200 1300	1.565 1.61	1.0	.052	.045	-.007

Comparison of chart recorded precipitation amounts vs inputs estimated from Control Flow Data.

Date/ Test No.	CONTROL FLOW DATA			CHART DATA			Estimated precipitation Control Flow (Ave. rate) x duration	Estimated precip. from chart	- =chart under + =chart over
	Time Period	Flow Rate (in/hr)	Ave. Flow Rate (in/hr)	Time	Chart Level (in)	Test duration (hr)			
18 Nov 82 322-1A	0830-0900	.019		0900	1.355				
	1000-1030	.022	.021	1000	1.37	1.0	.021	.015	-.006
	1130-1200	.024	.023	1030 1130	1.37 1.395	1.0	.023	.025	+.002
	1300-1330	.025	.0245	1200 1300	1.395 1.415	1.0	.025	.020	-.005
	1430-1500	.026	.0255	1330 1430	1.415 1.445	1.0	.026	.030	+.004
	1600-1630	.025	.0255	1500 1600	1.445 1.46	1.0	.026	.015	-.011
18 Nov 82 322-1B	0830-0900	.023		0900	1.43				
	1000-1030	.013	.018	1000	1.445	1.0	.018	.015	-.003
	1130-1135 1135-1200	.006 .033	.010	1030 1130	1.445 1.460	1.0	.010	.015	+.005
	1300-1330	.018	.026	1200 1300	1.46 1.49	1.0	.026	.030	+.004
	1430-1500	.031	.025	1330 1430	1.49 1.495	1.0	.025	.005	-.020
	1600-1630	.030	.0305	1500 1600	1.495 1.51	1.0	.031	.015	-.016
19 Nov 82 323-1A	1022-1030	.026		1030	1.490				
	1130-1200	.026	.026	1130	1.50	1.0	.026	.010	-.016
	1300-1330	.023	.0245	1200 1300	1.505 1.530	1.0	.025	.025	0
	1430-1500	.022	.0225	1330 1427 1430	1.530 1.550 1.575	1.0 Gage was	.023 bumped	.020	-.003
	1600-1615	.022	.022	1500 1600	1.925 1.59	1.0	.022	.015	-.007

Comparison of chart recorded precipitation amounts vs inputs estimated from Control Flow Data.

Date/ Test No.	CONTROL FLOW DATA			CHART DATA			Estimated precipitation Control Flow (Ave. rate)x duration	Estimated precip. from chart	- =chart under + =chart over
	Time Period	Flow Rate (in/hr)	Ave. Flow Rate (in/hr)	Time	Chart Level (in)	Test duration (hr)			
22 Nov 82 326-1A	0840-0900	.110		0900	1.59				
	1000-1030	.107	.1085	1000	1.69	1.0	.109	.100	-.009
	1130-1200	.103	.105	1030 1130	1.69 1.79	1.0	.105	.100	-.005
	1300-1330	.098	.1005	1200 1300	1.79 1.885	1.0	.101	.095	-.006
	1430-1500	.094	.096	1330 1430	1.887 1.98	1.0	.096	.095	-.001
22 Nov 82 326-1B	0840-0900	.019	.016	0900	1.845				
	1000-1015 1015-1030	.011 .016		1000	1.86	1.0	.016	.015	-.001
	1130-1200	.049	.055	1030 1130	1.86 1.905	1.0	.005	.045	-.010
	1300-1330	.043	.046	1200 1300	1.905 1.945	1.0	.046	.040	-.006
	1430-1500	.039	.041	1330 1430	1.945 1.99	1.0	.041	.045	+.004
23 Nov 82 327-1A	0830-0900	.085		0900	1.385				
	1000-1030	.086	.0855	1000	1.455	1.0	.086	.070	-.016
	1130-1200	.089	.0875	1030 1130	1.455 1.54	1.0	.088	.085	-.003
	1300-1330	.089	.089	1200 1300	1.54 1.625	1.0	.089	.085	-.004
	1430-1500	.087	.088	1330 1430	1.625 1.71	1.0	.088	.085	-.003
	1600-1630	.081	.084	1500 1600	1.71 1.795	1.0	.084	.085	+.001

Comparison of chart recorded precipitation amounts vs inputs estimated from Control Flow Data.

Date/ Test No.	CONTROL FLOW DATA			CHART DATA			Estimated precipitation Control Flow (Ave. rate)x duration	Estimated precip. from chart	- =chart under + =chart over
	Time Period	Flow Rate (in/hr)	Ave. Flow Rate (in/hr)	Time	Chart Level (in)	Test duration (hr)			
23 Nov 82 327-1B	0830-0900	.088		0900	1.455				
	1000-1030	.089	.0885	1000	1.53	1.0	.089	.075	-.014
	1130-1200	.094	.0915	1030 1130	1.53 1.61	1.0	.092	.080	-.012
	1300-1330	.096	.095	1200 1300	1.61 1.705	1.0	.095	.095	0.0
	1430-1500	.096	.096	1330 1430	1.705 1.79	1.0	.096	.085	-.011
	1600-1630	.092	.094	1500 1600	1.79 1.88	1.0	.094	.090	-.004
29 Nov 82 333-1A	0900-0930	.043		0930	1.365				
	1100-1130	.045	.044	1100	1.425	1.5	.066	.060	-.006
	1300-1330	.044	.0445	1130 1300	1.425 1.490	1.5	.067	.065	-.002
	1500-1530	.045	.0445	1300 1500	1.490 1.550	1.5	.067	.060	-.007
	1700-1730	.043	.044	1530 1700	1.550 1.610	1.5	.066	.060	-.006
	1928-1943	.041	.042	1730 1930	1.610 1.695	2.97	.083	.085	+.002
	2245-2315	.038	.0345	1945 2245	1.695 1.820	3.03	.120	.125	+.005
29 Nov 82 333-1B	0900-0930	.040		0930	1.45				
	1100-1130	.040	.040	1100	1.505	1.5	.060	.055	-.005
	1300-1330	.037	.0385	1130 1300	1.505 1.555	1.5	.058	.050	-.008
	1500-1530	.037	.037	1330 1500	1.555 1.605	1.5	.056	.050	-.006
	1700-1730	.024	.0305	1530 1700	1.605 1.650	1.5	.046	.045	-.001
	1928-1943	.015	.0195	1930	1.680	1.97	.038	.030	-.009
	2245-2315	.012	.0135	1945 2245	1.680 1.720	3.03	.041	.040	-.001

GPO 847-428